National Transportation Safety Board

Washington, D.C. 20594

Office of the Chairman

December 11, 2000

Professor Oetarjo Diran
National Transportation Safety Committee
Gedung Karsa Lt. 02
Departemen Perhubungan dan Telekomunikasi
JL Medan Merdeka Barat No 08
Jakarta 10110
Indonesia

Dear Professor Diran:

The National Transportation Safety Board participated in the National Transportation Safety Committee's (NTSC) investigation of the December 19, 1997, accident involving SilkAir flight MI185 as the State of Design and Manufacture of the accident airplane, a Boeing 737, as provided in Annex 13 to the Convention on International Civil Aviation. The Safety Board provided a U.S. Accredited Representative and technical advisors from its investigative staff as resources to the investigation. Additionally, Boeing, the Federal Aviation Administration, and Pratt and Whitney provided technical advisors.

The Safety Board is pleased to provide comments on the NTSC's draft final report. Please note that our review of the draft final report revealed that several sections require correction, clarification, or the inclusion of additional information. Of greatest concern are the statements in the draft final report that the "NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders" and the "investigation has yielded no evidence to explain the cause of the accident." Additionally, the draft final report contains recommendations that are not supported by the factual evidence.

The examination of all of the factual evidence is consistent with the conclusions that 1) no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and 2) the accident can be explained by intentional pilot action; specifically, a) the accident airplane's flight profile is consistent with sustained manual nose-down flight control inputs, b) the evidence suggests that the cockpit voice recorder was intentionally disconnected, c) recovery of the airplane was possible but not attempted, and d) it is more likely that the nose-down flight control inputs were made by the captain than by the first officer.

The detailed comments on the final report are enclosed. These comments are submitted pursuant to Section 6.9 of Annex 13 to the Convention on International Civil Aviation.

Sincerely,

[redacted]

Jim Hall
~~Acting~~ Chairman

Enclosure

National Transportation Safety Board

Washington, D.C. 20594

Office of Aviation Safety

DEC 11 2000

Professor Oetarjo Diran
National Transportation Safety Committee
Gedung Karsa Lt.02,
Departemen Perhubungan dan Telekomunikasi
JL. Medan Merdeka Barat No 08
Jakarta 10110
INDONESIA

Dear Professor Diran:

Attached are comments on the National Transportation Safety Committee's draft final report of the aircraft accident involving Silk Air flight MI185, which crashed on December 19, 1997 in the Musi River, Palembang, Indonesia. These comments are submitted pursuant to Section 6.9 of Annex 13 to the Convention on International Civil Aviation.

Please contact me if you have any questions about this submission.

Sincerely,

[redacted]

Thomas E. Haueter
Deputy Director
Office of Aviation Safety

Comments on Draft Final Report of Aircraft Accident Submitted by the Accredited Representative of the United States National Transportation Safety Board

SUMMARY

Introduction

As the state of Design and Manufacture of the Boeing 737 airplane, a United States Accredited Representative and advisors[1] participated in all aspects of the Republic of Indonesia's National Transportation Safety Committee (NTSC) investigation into the December 19, 1997, crash of SilkAir flight MI185 in the Musi River, Palembang, Indonesia. On October 17, 2000, the Safety Board received the NTSC's draft Final Report. These comments are submitted pursuant to Section 6.9 of Annex 13 to the Convention on International Civil Aviation, which provides that the State conducting the investigation "shall either amend the draft Final Report to include the substance of the comments received, or append the comments to the Final Report."

Review of the draft Final Report revealed that several sections require correction, clarification, or the inclusion of additional information. Of greatest concern are the statements in the draft Final Report that the "NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders" and the "investigation has yielded no evidence to explain the cause

A significant amount of pertinent factual information developed during the 3-year investigation is either not discussed in the draft Final Report or not fully considered in analyzing the cause of the accident. In particular, the draft Final Report does not take into account all of the investigative findings of the Human Performance Group (HPG), which were documented in a report produced July 30, 1999, and identified as version 6.0. This version of the HPG report was the only version that was developed through consensus agreement among the group members, which included representatives from the Indonesian AAIC (who served as Group Chairman), the Singapore CAA, the United States NTSB, and the Australian BASI.[2] Relevant content from version 6.0 of the HPG report is provided later in this document in connection with specific comments on individual sections in the draft Final Report. Among other things, version 6.0 of the report contains comprehensive information about the flight crewmembers, including information about

[1] Advisors to the U.S. Accredited Representative included representatives from the Federal Aviation Administration, Boeing Commercial Airplane Group, United Technologies, and Pratt and Whitney.

[2] The HPG provided version 6.0 of its report to the NTSC; however, the document that was designated by the NTSC as the final HPG report (without consensus agreement from the HPG members) omits a significant amount of information that was included in version 6.0.

their professional, personal, and financial backgrounds. For example, substantial information was developed indicating that the captain's professional and financial situations had undergone negative changes in the months preceding the accident. It is disappointing that much of this information was either omitted from the draft final report or was not fully analyzed.

Following this summary, this document suggests specific corrections, clarifications, and/or additions for each section of concern. This summary provides an overview of the primary areas of concern and offers an explanation for the accident that is consistent with all of the evidence. As further discussed in this summary, when all of the investigative evidence is considered, it leads to the conclusions that: 1) no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and 2) the accident can be explained by intentional pilot action. Specifically, a) the accident airplane's flight profile is consistent with sustained manual nose-down flight control inputs; b) the evidence suggests that the cockpit voice recorder (CVR) was intentionally disconnected; c) recovery of the airplane was possible but not attempted; and d) it is more likely that the nose-down flight control inputs were made by the captain than by the first officer.

<u>1. No airplane-related mechanical malfunctions or failures caused or contributed to the accident.</u>

The investigation examined the aircraft structures, flight control systems, and powerplants extensively, and the results are presented in the NTSC draft Final Report. As stated in the conclusions in the draft Final Report, there was no evidence of any pre-impact mechanical malfunctions or failures. Further, the pilots did not report any problems with the airplane or make any distress calls to air traffic controllers throughout the duration of the flight, as would be expected if they had experienced a mechanical problem. Finally, engineering simulations of flightpath data (derived from pre-upset DFDR data, recorded radar information, and wreckage locations) were conducted to determine the motion of the airplane from the time it departed cruise flight until the end of recorded data indicated. As noted in the NTSC draft Final Report, analysis of these simulation results indicated that no single mechanical failure of the airplane structure or flight control systems would have resulted in movement of the airplane through recorded radar data points. Further, there was no evidence of any combination of systems failures.

Therefore, the evidence supports a conclusion that no airplane-related mechanical malfunctions or failures caused or contributed to the accident.

2. The accident can be explained by intentional pilot action.

a) The accident airplane$ flight profile is consistent with sustained nose-down manual flight control inputs.

The engineering simulations just discussed indicated that manual manipulation of the primary flight controls in multiple axes would result in a descent time history that was similar to the last recorded radar points. Without the use of horizontal stabilizer trim, this would require control column forces greater than 50 pounds and large control column inputs; if those forces were relaxed, the airplane would have initiated a return to a nose-up attitude due to its inherent stability. However, the simulations indicated that a combination of either control column inputs and/or changing the stabilizer trim from about 4.5 to 2.5 units nose-down trim (which would have "unloaded" the high control forces) in conjunction with aileron inputs, would result in a descent time history similar to that of the last recorded radar points. It is important to note that the physical evidence indicated that the horizontal stabilizer trim was set at the maximum airplane nose-down main electric trim limit (2.5 units) at the time of impact.

Therefore, on the basis of the engineering simulations, it is very likely from the time it departed from cruise flight until the end of the recorded data, that the airplane was responding to sustained flight control inputs from the cockpit.

b) The evidence suggests that the CVR was intentionally disconnected.

The NTSC draft Final Report states that no reason could be found for the stoppage of the flight recorders and recommends that "a comprehensive review and analysis of [FDR and CVR] systems design philosophy by undertaken . . . to identify and rectify latent factors associated with the stoppage of the recorders in flight." This recommendation implies that the NTSC believes the flight recorders stopped because of mechanical malfunction. However, this implied conclusion is not supported by the evidence. Rather, the evidence suggests that the CVR was intentionally disconnected. There is also no evidence to indicate that the digital flight data recorder (DFDR) stopped as a result of mechanical malfunction.

The first indication of an anomaly in the flight occurred at 09:05:15.6, when the CVR ceased recording. As further discussed later in this document in detailed comments on section 2.6.1 of the draft Final Report, evidence (including the sound signature at the end of the recording) indicated that the stoppage of the CVR was consistent with the removal of power going to the unit through activation ("pulling") of the circuit breaker, rather than the CVR stopping as a result of a mechanical malfunction or a short circuit or other electrical condition.[3] Further, the evidence from the last recorded minutes on the CVR indicates that during the 4 minutes that elapsed after the last meal service and before the recording stopped, only the captain and first officer were present in the cockpit. The

[3] The DFDR gave no indication of any other electrical problems associated with the cessation of the CVR or electrical problems preceding the subsequent cessation of the DFDR.

HPG determined that the captain's statement at 0904:55, "go back for a while, finish your plate," indicated that he was leaving the cockpit and told the first officer to finish eating. In addition, the CVR also recorded sounds that were consistent with seat movement and removal of a seat belt just before the captain offered the first officer water at 0905:00. This sequence of events is consistent with the captain preparing to leave the cockpit.

The circuit breaker panel located directly behind the captain's seat contains the circuit breakers for both the CVR and FDR. It was determined that the cockpit door did not open before the CVR ceased recording at 0905:15.6, thus it is evident that the captain would have been in the best position to manually pull the CVR circuit breaker at the time that it stopped. (It should be noted that the captain had pulled a CVR circuit breaker on a previous occasion.[4])

The DFDR stopped recording approximately 6 minutes after the CVR stopped recording. There was no evidence of any malfunction of the DFDR until the moment it stopped recording. Examination of other aircraft systems and the review of the air traffic control radar tapes revealed that the DFDR is powered through the same electrical bus (Electronics Bus 1) as ATC-1 (one of the airplane's two radar transponders) and the Mach trim actuator. The radar transponder (which was likely ATC-1 during the accident flight)[5] continued to operate and return data for a short time after the DFDR stopped. In addition, the Mach trim actuator was found at its high speed (not cruise speed) setting, indicating that it was powered and operational during the airplane's high-speed dive. It can be concluded that the absence of a malfunction of the DFDR up to the point at which it stopped, combined with the fact that the transponder continued to transmit and the Mach trim actuator continued to operate after the DFDR had stopped, indicates that the stoppage was not due to a loss of power to Electronics Bus 1. However, the stoppage could be explained by someone manually pulling the circuit breaker.

The NTSC draft Final Report suggests that the cessation of the CVR and DFDR could in each case be explained by a broken wire. Although this is technically correct, the probability of two such unrelated wire breaks occurring several minutes apart and affecting only the CVR and DFDR is so highly improbable that it cannot be considered a realistic possibility.

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[4] The NTSC draft Final Report acknowledges this incident in section 2.14.3, which describes the incident as follows: "for non-technical reasons the PIC infringed a standard operating procedure, i.e., with the intention to preserve a conversation between the PIC and his copilot, the PIC pulled out the CVR circuit breaker, but the PIC reset the circuit breaker in its original position before the flight."

[5] The radar transponder can also be powered through ATC-2, which operates off of Electronics Bus 2. However, it was reported to NTSB investigators by SilkAir instructor pilots that SilkAir operating procedure (as documented in company procedures appended to the 737 operating manual) called for the pilots to select ATC-1 when the captain was flying and ATC-2 when the first officer was flying unless one was inoperative. Because the captain was flying during the accident flight, pursuant to this procedure, ATC-1 would have been selected.

c) Recovery of the airplane was possible but not attempted.

The NTSC draft Final Report contains a recommendation that flight crews be trained in "recovery from high speed flight upsets beyond the normal flight envelope...to enhance pilot awareness on the possibility of unexpected hazardous flight situations." This recommendation implies that the NTSC has concluded that the accident may have been caused by an unexpected unusual flight upset and that the flight crew was not properly trained to recover from such an upset. However, such a conclusion is not supported by the evidence.

Regardless of the reason for the airplane's departure from cruise flight, it could have been easily recovered using conventional techniques that both pilots had received training for and that were within the capabilities of both pilots. Further, there was ample time for the pilots to take such corrective action to return the airplane to a straight and level attitude and flight. Both pilots had training in unusual attitudes, and the captain was an accomplished fighter pilot adept at aerobatic maneuvers as evidenced by his membership on the RSAF flight demonstration team, the "Black Knights." It is apparent that, had the pilot attempted to recover by initiating immediate corrective action using standard flight control inputs and techniques, the airplane would have recovered to a straight and level attitude with a minimum loss of altitude.

As previously mentioned, the simulations indicate that from the time it departed cruise flight, a sustained nose-down flight control input was necessary to maneuver the airplane through the recorded radar points. Additionally, the impact damage to the engine was consistent with a higher-than-cruise power setting. (Without pilot input, the autothrottle system would have reduced engine power to idle when the descent began; therefore, the high power setting must have been input by the pilot.) Further, there was no evidence that any other measures were taken (such as deploying aerodynamic drag devices on the airplane) to slow the airplane's speed. The wing leading-edge devices and trailing-edge flaps, the "speed brakes" (in-flight spoilers) and the landing gear were found to have been in a position that was consistent with cruise flight.

The simulation results, in combination with the physical evidence of a high engine power setting, a horizontal stabilizer trim setting positioned for maximum nose-down attitude, and the absence of any indication of an attempt to reduce the airplane's speed, are clearly inconsistent with an attempt to a recover from a dive and return to cruise flight, and strongly suggest the maneuver was intentional.

d) It is more likely that the nose-down flight control inputs were made by the captain than by the first officer.

The HPG evaluated the professional, personal, and financial backgrounds of the flight crew of flight MI185. The HPG findings are discussed in more detail in comments on individual sections of the draft Final Report later in this document. In summary, the HPG investigation revealed that both pilots were trained in accordance with applicable company and civil aviation authority regulations and were competent to promptly recognize, address, and manage an unanticipated in-flight situation using all resources available to them; there was no evidence to indicate that the performance of either pilot was adversely affected by any medical or physiological condition existing before the accident; there was no evidence to indicate that there were any difficulties in the relationship between the two pilots before or during the accident flight; and there was no evidence that either pilot was experiencing any significant difficulties in personal relationships involving family and friends.

Further, with respect to the first officer, the evidence developed by the HPG revealed the first officer was not experiencing any professional setbacks or difficulties at the time of the accident, nor was he experiencing any financial difficulties. Also, there was no evidence that he was experiencing any behavioral changes before the accident.

However, the investigation of the captain's background developed evidence that revealed he had experienced multiple work-related difficulties, particularly during the 6-month period before the accident. Additionally, the investigation found that the captain was experiencing significant financial difficulties about the time of the accident, and there were indications that the captain's behavior and lifestyle had changed before the accident.

It is not possible to determine with certainty which pilot made the manual flight control inputs. However, when the HPG findings are considered in the context of all the other investigative findings, they lead to the conclusion that the airplane departed cruise flight as a result of an intentional maneuver requiring sustained manual flight control inputs that were most likely performed by the captain.

In summary, the investigative findings strongly support the conclusions that no airplane-related mechanical malfunctions or failures caused or contributed to the accident, and the accident can be explained by intentional pilot action.

The remainder of this document sets forth detailed comments on individual sections in the draft Final Report.

1. FACTUAL INFORMATION

1.1 History of Flight

Sequence of Events

On 19 December 1997, a SilkAir Boeing B737-300 aircraft, registration 9V-TRF, was on a scheduled commercial international passenger flight under Instrument Flight Rules (IFR), routing Singapore – Jakarta – Singapore.

The flight from Singapore to Jakarta operated normally. After completing a normal turn-around in Jakarta the aircraft departed Soekarno-Hatta International Airport for the return leg.

At 08:37:13 (15:37:13 local time) the flight (MI 185) took off from Runway 25R with the Captain as the handling pilot. The flight received clearance to climb to 35,000 feet (Flight Level 350) and to head directly to Palembang[6]. At 08:47:23 the aircraft passed FL245. Ten seconds later, the crew requested permission to proceed directly to PARDI[7]. The air traffic controller instructed MI 185 to standby, to continue flying directly to Palembang and to report when reaching FL350. At 08:53:17, MI 185 reported reaching FL350. Subsequently, the controller cleared MI 185 to proceed directly to PARDI and to report when abeam Palembang.

At 09:05:15.6, the cockpit voice recorder (CVR) ceased recording. According to the Jakarta ATC transcript, at 09:10:18 the controller informed MI 185 that it was abeam Palembang. The controller instructed the aircraft to maintain FL350 and to contact Singapore Control when at PARDI. The crew acknowledged this call at 09:10:26. There were no further voice transmissions from MI 185. The last readable data from the flight data recorder (FDR) was at 09:11:27.4. Jakarta ATC radar recording showed that MI 185 was still at FL350 at 09:12:09. The next radar return, eight seconds later, indicated that MI 185 was 400 feet below FL350 and a rapid descent followed. The last recorded radar data at 09:12:41 showed the aircraft at FL195. The empennage of the aircraft subsequently broke up in flight and the aircraft crashed into the Musi River delta, about 28 kilometres north east of Palembang. The accident occurred in daylight and in good weather condition.

The route map and the crash site are depicted in Figures 1.a to c. The sequence of events is shown schematically in Figure 2.

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[6] *Coordinates (02.52.7S, 104.39.2E)*

[7] *Air Traffic Control reporting point (00.34.0S, 104.13.0E) north of Palembang in the Jakarta FIR near the boundary with the Singapore FIR. At PARDI, flights are transferred over to Singapore ATC*

Section 1.1 in the NTSC's draft Final Report does not present all factual information necessary to portray a more complete picture of the flight crewmembers' interaction in the cockpit shortly after departure from Jakarta. It is strongly suggested that this section be revised to include information from the HPG Final report (dated June 8, 2000), which provides a time history of the captain's movements in the cockpit in relation to the time that the CVR stopped recording. Once this history is established, it provides a basis for analyzing the stoppage of the CVR and, possibly, the DFDR. The following text should be inserted immediately before the sentence, "At 09:05:15.6, the cockpit voice recorder (CVR) ceased recording":

> At 0904:55, the PIC said "go back for a while, finish your plate." The co-pilot responded "I am." A series of metallic snaps started immediately prior to 0905:00, when the PIC said "some water."The

Further, the CVR transcript in Appendix A is not a complete factual record of CVR recording that was transcribed by the CVR group. Appendix A does not include the conversation that took place during preflight activities or the conversations that transpired between the flight crewmembers or between the flight crew and the cabin crew while the airplane was on the ground in Jakarta. This information is critical to the analysis of crewmembers' overall discipline and of comments that were made in conversation by the crewmembers. Seen in its entirety, the CVR transcript indicates that a cordial and professional atmosphere existed on the flight deck during the period of time the CVR was operating. Moreover, the publication of the entire CVR transcript is necessary to maintain consistency with the ATC communications transcripts.

1.5 Personnel Information

1.5.1 Pilot-In-Command (PIC)

Sex	*Male*
Age	*41 years*
Date of joining SilkAir	*1 March 1992*
Licence country of issue	*Singapore*
Licence type	*ATPL (Airline Transport Pilot Licence)*
Licence number	[redacted]
Validity period of licence	*1 November 1997 to 30 April 1998*
Ratings	*Boeing B737; Airbus A310 (not current)*
Medical certificate	*First class – issued 10 October 1997*
Aeronautical experience	*7173.3 hours*
Experience on type	*3614.7 hours*

Last 24 hours	*1.6 hours*
Last 7 days	*20.1 hours*
Last 28 days	*56.8 hours*
Last 90 days	*216.7 hours*
Last line check	*25 January 1997*
Last proficiency check	*7 August 1997*
Instrument rating check	*7 August 1997*

1.5.2 First Officer (F/O)

Sex	*Male*
Age	*23 years*
Date of joining SilkAir	*16 September 1996*
Licence country of issue	*Singapore*
Licence type	*CPL (Commercial Pilot Licence)*
Licence number	[redacted]
Validity period of licence	*1 July 1997 to 30 June 1998*
Ratings	*Boeing B737*
Medical certificate	*First class – Issued 4 June 1997*
Aeronautical experience	*2501.7 hours*
Experience on type	*2311.8 hours*
Last 24 hours	*1.6 hours*
Last 7 days	*21.4 hours*
Last 28 days	*69.8 hours*
Last 90 days	*217.6 hours*
Last line check	*10 October 1997*
Last proficiency check	*15 September 1997*
Instrument rating check	*15 September 1997*

Sections 1.5.1 and 1.5.2 do not contain any information about the captain\$ personal background. Although this is not a typical subheading for an accident report, the high probability of flight crew involvement in this accident makes it necessary to include this information to complete the factual record and provide the basis for a thorough analysis.

It is strongly suggested that the NTSC add a section pertinent to the captain\$ personal background information to the draft Final Report. This section should be identified as ‶1.5.1.1 Personal Background"and include the following information about the captain:

- **The captain was born [redacted] 1956 in Singapore. His parents were Chinese immigrants, and he was the second of four children. He was of Buddhist faith, but he was not reported to be devoutly religious.**

- **He achieved his 'O"level education in 1972 and an industrial technician certificate in electronics in 1974.**

- **The captain was married in July 1979, and his wife, also of Chinese descent, was born in Singapore. The captain and his wife had three sons, born in 1981, 1983, and 1989. In HPG interviews during the investigation, the captain was described as being a family man, who often spoke about his sons and spent a lot of time with them.**

- **The captain's family moved to a new house in August 1997 next to where the captain's brother and parents lived. He was reported to be interested in computers and financial markets.**

- **According to police representatives, he had no record of criminal activity in Singapore.**

It is also strongly suggested that the NTSC add a section pertinent to the first officer's personal background information. This section should be identified as '1.5.2.1 Personal Background"and include the following information:

- **The first officer was born in New Zealand on [redacted] 1974. He was the second of four children. The first officer was not married but had a close personal relationship with a stewardess who worked at SilkAir. The first officer lived with another SilkAir first officer, a close friend who he also lived with when working for Garuda.**

- **The first officer was a Christian, and was described as being devout. He was described as being close to his family and had a number of close friends in Singapore. He was described as being very interested in flying and pursuing a flying career. His other interests were reported to include traveling, spending time with friends, and playing sport.**

- **Police representatives reported that the first officer had no record of criminal activity in Singapore.**

1.16 Tests and Research

1.16.1 CVR Circuit Breaker Actuation Test

Upon the completion of data readout by NTSB, the CVR was taken to AlliedSignal on 22 January 1998 for further testing. This testing was an attempt to verify if the termination of the CVR recording was due to loss of power by the pulling of the CVR circuit breaker *or other means. The result was inconclusive. Therefore other tests had to be performed, see Appendix F.*

There were three tests conducted in a B737-300 aircraft to investigate the CVR circuit breaker actuation sound signature.

The first test

The first test was carried out on the ground by NTSB and Boeing on 5 February 1998. The reason for this test was to have quiet ambient condition to provide the best opportunity for detection of circuit breaker actuation sound signature. The result showed that the CVR cockpit area microphone did record the CVR circuit breaker actuation. Actuation of a circuit breaker nearby gave a similar result.

The second test

The test (consisting of on-ground and in-flight tests) was conducted on 14 May 1998 and 15 May 1998 by NTSB.

The purpose of the ground test was to obtain an on-plane, on-ground CVR recording of the CVR circuit breaker actuation, and the purpose of the flight test was to obtain an on-plane, in-flight CVR recording of the CVR circuit breaker opening. In both tests the circuit breaker was actuated manually and through the introduction of faults to the aircraft's wiring, i.e. short circuit and overload.

The results of these tests were compared with the accident CVR recording sound signatures. In the short circuit tests a distinctive 400 Hz tone is recorded on one or more of the CVR channels. No corresponding signatures could be identified on the accident recording. The same tests found that the area microphone is able to pick up a distinctive and identifiable snap sound that the circuit breaker makes when it is violently tripped by a short circuit. (Note: The CVR continues to run for 250 milliseconds before it runs out of power from the capacitor. As sounds travel about one foot per millisecond, it would take only six milliseconds to travel the approximately six feet distance from the circuit breaker to the area microphone. Hence the CVR is able to record the snap sound of the circuit breaker.)

The overload tests yielded similar results as the short circuit tests except that there was a slight time delay for the circuit breaker to trip and the snap sound was quieter but still identifiable. No corresponding sound signatures could be found in the accident recording.

The last set of tests was to examine the sound signatures when the CVR circuit breaker was manually pulled. The snap sound was identifiable on the ground without engines and air-conditioning operating. However in the flight tests, the addition of the background cockpit noise present during normal cruise obscures the sounds associated with the *manual in-flight pulling of the cockpit circuit breaker. No corresponding sound signatures could be found in the accident recording.*

The summaries of the results of the second tests are as follows:

- *During an overload and a short circuit, the sound of the circuit breaker popping is loud enough to be identified on the CVR's area microphone channel, both on the ground and in-flight.*
- *During an overload and a short circuit, the CVR records unique and identifiable sound signature on one or more of the channels, both on the ground and in-flight.*
- *During the manual pull test on the ground, the sound of the circuit breaker is loud enough to be identified on the CVR recording.*
- *In cruise flight, normal cockpit background noise obscured the manual circuit breaker pull sounds. There are no unique electronic identifying sound signature recorded on the CVR.*

The third test

The test was conducted in-flight using a B-737 SilkAir sister aircraft in Singapore on 16 October 1998 and supervised by the Indonesian NTSC, an FAA avionic inspector (representing NTSB) and Singapore MCIT representatives.

In the third test, several scenarios were performed where the CVR circuit breaker in the cockpit was manually pulled. The manual pulls were categorized as "soft", "hard" and "string" pull. The soft pull was by pulling the circuit breaker with minimum noise. The hard pull was by pulling the circuit breaker normally. The string pull was by pulling on a string that was attached to the circuit breaker. This was to simulate a short circuit causing the circuit breaker to pop out.

All the tests were conducted with an identical AlliedSignal SSCVR 2-hours recorder as installed in the accident aircraft.

All four channels of the CVR recordings of the above three tests were analyzed using the same NTSB signal processing software that was used to analyze the accident CVR recording.

Several tests were done to document the sound that were recorded on the CVR during a soft, hard and string pull of the CVR circuit breaker. The test closely matched the data obtained from the second test (NTSB in-flight test above).

The NTSC draft Final Report's discussion about the CVR (and DFDR later in the report) requires a correction of terms so as to avoid confusion when referencing the electrical power that is being supplied to both recorders. The "power source" is where the CVR and DFDR receive their respective electrical power from within the aircraft whereas the "power supply" is a component that is integral to the CVR and

DFDR units. The use of 'power supply' when describing a power interruption from the aircraft power source is incorrect because it implies that an internal failure occurred or may have occurred within a respective recorder. To eliminate any potential confusion regarding the electrical power being supplied to the CVR and DFDR, the draft Final Report should be reviewed and the term 'electrical power source' inserted where the term 'power supply' is currently used.

In addition, examination and testing requested by the NTSC revealed no evidence to suggest that a mechanical malfunction or failure of either the CVR or DFDR caused either recorder to stop recording data.

The discussion of the postaccident CVR testing does not address the distinctive 400 Hz tone (or 'hum') that was recorded on the CVR tape. For purposes of clarity, the following information (an excerpt summary from the February 20, 1998, Boeing test report) should be added to this section to discuss the basis for the 400 Hz tone:

> **Power line hum components, located at multiples of 400 HZ were evident in the CVR area microphone signal. The level of some of these hum components increased when the overload was applied until the circuit breaker popped. These levels were even more dramatic during the ground fault conditions.It should be noted that some of these hum components persisted in the signal, after the breaker has opened, to the very end of the recorded data. Tones are good candidates for detection amongst broadband boundary layer excitation. Tracking the amplitude of a particular power-line hum component may indicate circuit overload or faults.**

1.18.3 PIC's Background and Training

1.18.3.1 Professional Background in RSAF

The PIC joined the Republic of Singapore Air Force (RSAF) as a pilot trainee on 14 July 1975. He obtained his 'wings' (fully operational) on 25 March 1977. During his RSAF career, the PIC flew many different types of fighter and training aircraft. He held senior flying and instructing positions. In 1970s, the PIC was selected to joint the RSAF's Black Knights aerobatic team. He reached the rank of Captain in 1980 and was promoted to Major in 1989. In 1991, the PIC applied to leave the RSAF under a voluntary early release scheme. The PIC met the eligibility requirements for the early release scheme as he was 35 years old and had at least six years in his immediate preceding rank. His application was accepted.

The PIC's reason to leave RSAF and join SilkAir was to keep flying and to spend more time with his family.

The PIC obtained a US Federal Aviation Administration (FAA) Commercial Pilot Licence on 19 November 1991 and an Air Transport Pilot Licence on 26 November 1991 in Benton Kansas. He left full-time employment in the RSAF on 29 February 1992. He had approximately 4,100 hours flying experience at that time. The PIC served as a squadron pilot in the RSAF on a part-time basis from 1 March 1992 to 30 April 1993. He subsequently served in the military reserve, as a Major, in a non-flying capacity. In January 1997, the PIC was promoted to Deputy Director Air Liaison Officer in his reserve unit.

The NTSC draft Final Report's description of the captain's "Professional Background in RSAF" should be expanded to include information developed by the HPG regarding his military service or significant events that occurred during his service period. It is strongly recommended that section 1.18.3.1 be revised to include the following information:

> **The captain joined the RSAF as a pilot trainee on July 14, 1975. He obtained his "Wings" (fully operational) on March 25, 1977. During his RSAF career, the captain flew many different types military fighter and training aircraft. He held senior flying and instructing positions and reached the rank of captain (military) in 1980 and was promoted to the rank of major in 1989. The captain became a member of the RSAF Black Knights in 1990 [not 1970s as stated in the NTSC draft Final Report].**
>
> **In December 1979, when five RSAF pilots (including the captain) and four T/A-4S aircraft were temporarily stationed in the Philippines for training, the captain experienced the first of three significant events during his service in the military. On December 19, the captain was forced to withdraw from a scheduled training mission because of a mechanical problem with his aircraft. The other three aircraft continued with the training mission and collided with terrain after encountering bad weather in a mountainous area. All of the pilots on board the aircraft were killed. Although the HPG investigation obtained information about this event, it was not possible for the group to determine the extent to which the captain had been affected by this event.**
>
> **On September 6, 1981, the captain took off in an SF 260 training aircraft as the instructor pilot with a student pilot conducting the flying duties. During the takeoff roll, the aircraft crashed. The student was fatally injured. The RSAF investigation found the circumstances of the accident were not the responsibility of the captain.**

On March 3, 1986, the T/A-4S in which the captain was acting as an instructor pilot during a training flight experienced loss of control because of a mechanical malfunction. Both crewmembers ejected safely from the aircraft. The RSAF investigation found the captain was not responsible for the event.

During HPG interviews, RSAF personnel described the captain as being a highly skilled pilot. According to the RSAF, there were no records of the captain receiving disciplinary action or having any major setbacks in his career. It was also reported that the captain did not have a history of disagreements with other personnel while serving in the RSAF. However, several pilots who worked with the captain at SilkAir and who were in the RSAF at the same time as the captain reported that he had disagreements with his commander while serving with the Black Knights. The RSAF reported that these disagreements were related to flying maneuvers. The disagreements were characterized as minor and were reported to have been resolved. It was reported that the squadron was under a great deal of pressure and that there were disagreements between many pilots.

In 1991, the captain applied to voluntarily leave the RSAF under an early release program. The captain met the eligibility requirements for the early release (he was 35 years old and had at least 6 years in his immediate preceding rank), and his application was accepted shortly thereafter.

The captain obtained a United States Federal Aviation Administration (FAA) Commercial Pilot Certificate on November 19, 1991, and an Airline Transport Pilot Certificate on November 26, 1991, in Benton Kansas. He left the full-time employment of the RSAF on February 29, 1992, at which time he had accumulated approximately 4,100 hours flying experience.

The HPG investigation found during an interview with the captain's wife that he separated from the RSAF because he wanted to spend more time with his family. A person considered to be a flying associate of the captain reported that the captain probably left the RSAF in order to remain in a flying position because his next job would have likely been in a nonflying capacity if he remained enlisted. Under the early release scheme, the captain had the choice of joining either Singapore Airlines (SIA) or SilkAir. Several SilkAir personnel who knew the captain reported that he preferred to join SilkAir rather than SIA because he could be promoted to a command pilot position at SilkAir within 3 years whereas he would likely have to wait at least 5 years to achieve the same position at SIA.

Although the captain was flying full-time for SilkAir in March 1992, he served as a squadron pilot in the RSAF on a part-time basis from March 1, 1992, to April 30, 1993. He subsequently served in the military reserve, as a major, in a nonflying capacity and in January 1997 was promoted to Deputy Director Air Liaison Officer in his reserve unit.

1.18.3.2 Professional Background with SilkAir

The PIC formally joined SilkAir on 1 March 1992. He was initially employed as a Cadet pilot under a training program for pilots that did not have a Boeing 737 (B737) type rating and had no previous airline experience.

The PIC was assigned to the Airbus A310 fleet and commenced training on 30 May 1994. He was appointed First Officer on the aircraft on 15 August 1994. When SilkAir discontinued A310 operations, the PIC was re-qualified on the B737 in March 1995.

The PIC was selected for B737 command training on 22 October 1995. He was appointed Captain on 26 January 1996, and confirmed in that position on 27 July 1996.

He was selected as LIP in March 1997[8] and completed his training on 9 May 1997. He performed satisfactorily thereafter in this position. On 3 July 1997, the PIC was de-appointed from his LIP position following an investigation into an operational incident which occurred on 24 June (see Appendix I for details).

The PIC had no problems with regard to his professional licence medical requirements. His last licence renewal medical examination was on 2 December 1997.

Section 1.18.3.2 does not provide a complete factual record regarding the captain's career at SilkAir nor does the referenced Appendix I (the chronology presented in Appendix I does not list any professional events that occurred after August 19, 1997). The addition of a complete career chronology is necessary to accomplish a thorough analysis of the accident. Thus, it is strongly recommended that the NTSC include the following information (from version 6.0 of the HPG report) in section 1.18.3.2 to present a complete chronology of the captain's airline history:

The captain was formally employed with SilkAir on March 1, 1992, as a "cadet" pilot under a special training program for pilots who did not have a Boeing 737 (B737) type rating and had no previous airline experience. The captain signed a 7-year training bond agreement

8 The LIP position was seen as a requirement for further promotion to instructor pilot or into management. The position also gave a pilot additional allowance of S$ 750 monthly.

with SilkAir (then known as Tradewinds) that required the captain to pay the company on a prorated schedule for his training if he should leave the employ of SilkAir for any reason.

After completing B737 ground school, the simulator checks, and base checks, the captain was appointed as a second officer on June 26, 1992. At SilkAir, the second officer position is typically identified with a copilot who requires a mandatory period of supervision before promotion to first officer. It was a standard appointment for someone with the captain's background at the time he joined the airline. He was appointed as a first officer for a 6-month probation period on October 14, 1992, commenced line operations in that position, and completed his probation period on April 14, 1993.

The captain was selected for a conversion to the Airbus 310 (A310) fleet on April 14, 1994, and commenced training activities on May 30, 1994. He was appointed as a first officer on the aircraft on August 15, 1994. When SilkAir phased out its A310 fleet, the captain was eligible to leave SilkAir and join SIA. However, he decided to remain with SilkAir and subsequently completed B737 reactivation training in March 1995.

After obtaining sufficient flight time to convert his FAA issued Airline Transport Pilot License (ATPL) to a Singaporean license, the captain took a written examination (Special Assessment Paper for a Foreign License Conversion) on July 25, 1995. This examination was administered by the United Kingdom (UK) CAA under a contract with the Singaporean CAAS. Candidates are only given one opportunity to take this examination for which a passing score was 75 percent. The captain initially scored 68 percent but a subsequent rescoring elevated his score to 71 percent. On August 1, 1995, the captain made a special appeal to the UK CAA, citing that there were "imperfections" in the exam paper. His appeal was accepted and he was given a passing grade. He applied for a Singapore ATPL on October 11, 1995, and received a letter 7 days later from the SilkAir B737 Fleet Manager congratulating him on achieving his Singapore ATPL and 3 years of service at SilkAir.

The captain was selected for B737 command training on October 22, 1995,[9] and commenced training for this position on January 22, 1996. This training included both simulator and line training, with the simulator training consisting of five line-oriented flight training (LOFT) sessions. The captain signed a 3-year bond agreement with

[9] Pilots are not eligible for command selection in SilkAir before they have served 3 years in the company, flown a total of 4,400 hours, and completed 300 sectors as pilot flying.

SilkAir for the training. He was appointed to captain on January 26, 1996, and confirmed (after probation) in that position on July 27, 1996.

In March 1997, three management pilots in SilkAir[10] met to discuss the captain's suitability for a line instructor pilot (LIP) position.[11] Although the captain met the minimum requirements for the position, the managers initially had reservations about the captain's suitability as they thought he may have been too reserved, regimented, or strict. After interviewing the captain, they selected him for the position and he completed the required training between April 30, and May 9, 1997. He also conducted line operations as a LIP between May 10 and June 13, 1997. There were no problems reported concerning the captain's LIP performance.

During his career at SilkAir, the captain received training in unusual attitudes, flight control malfunctions, and flight instrument malfunctions on several occasions. No significant problems were noted regarding the captain's abilities to accomplish this training. During his last training session in these areas (February 17 to 18, 1997), his performance was rated as "sound." In May 1997, the captain participated in the Aircrew Resource Management course conducted within SIA for aircrews.

During 1992 to 1996, the captain was not involved in any known operational incidents. However, he was involved in three nonoperational incidents that SilkAir management described as minor and as having no effect on the captain's chances of career progression. These events involved missing a security briefing, forgetting his passport for an international flight, and attempting to cash a cheque at an inappropriate facility.

Between January 1997 and the time of the accident, the captain was involved in the following four operational events:

- On March 3, 1997, a go-around was performed on an approach into Manado, Indonesia;

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[10] These management pilots were the Flight Operations Manager, B737 Fleet Manager, and the F-70 Fleet Manager. The B737 fleet manager was the PIC's immediate supervisor.

[11] In SilkAir, a captain is eligible to be considered for an LIP position after serving as a captain for 1 year. In addition to regular duties as commander, LIPs at SilkAir give instruction and guidance to command candidates or first officers in the final stages of their training. At SilkAir, the LIP position was considered a requirement for further promotion to instructor pilot or into management. The position also gave a pilot additional pay of S$750 monthly.

- On May 17, 1997, a flight was conducted with a dispatch authorization for an inoperative parking brake;

- On June 24, 1997, the captain pulled, and then reset, the CVR circuit breaker before a flight; and

- On November 20, 1997, an overweight landing occurred in Singapore.

As a result of the CVR circuit breaker incident, the captain was removed from his LIP position on July 3, 1997, after a Divisional Inquiry. Although he subsequently appealed this decision, a Company Inquiry upheld the original decision. During the accident investigation, the HPG found through interviews with several SilkAir personnel that the captain was upset by the events that resulted in the loss of his LIP position. The events surrounding the four incidents are summarized in Appendix I of the draft Final Report (Appendix H1 of the HPG version 6.0 report).

During interviews conducted by the HPG, SilkAir instructors reported that the captain's transition from military fighter aircraft to a commercial airliner was average but that his performance soon improved with experience. He adapted quickly and generally had no problems with any period of training. Further, SilkAir evaluates each pilot's operational performance every 6 months. These base checks are performed in a simulator, and the pilot's performance is rated in a number of key performance areas. The captain's performance on almost all base checks from March 1993 to his last check on August 7, 1997, was rated as "above average." His performance on the annual line checks was consistent with his performance on base checks.

Interviews conducted by the HPG with instructors and other pilots at SilkAir indicated that the captain's ability as a pilot was above average and that he was a competent operator. He was commonly described as being very highly skilled in handling an aircraft and as having fast reaction times. It was reported that he appeared to maintain good situation awareness and that he made decisions quickly, firmly, and confidently. He also appeared to be able to handle any flight-related pressures quite calmly.

The captain was described by other SilkAir pilots as a good cockpit manager. They indicated that he provided clear instructions, kept first officers informed of his decisions, and let first officers make their own decisions. He was quick to spot copilot mistakes or problems with

the flight. However, he was not known for criticizing copilots, and liked to teach and show them new ways of doing things.

The HPG interviews of SilkAir pilots also revealed the captain to be someone who operated 'by the book' and who would not exceed aircraft limitations. However, many pilots also indicated the captain would vary from normal practices at times. For example, several copilots reported the captain would often push the aircraft's speed beyond the economy speed of .74 mach.[12] There were also several reports of the captain performing higher than normal approaches[13] and, unlike other company captains, exploring ways of varying normal practices to reduce flight durations. Although the captain was not generally regarded as an unsafe pilot, he was regarded as a pilot who made his own decisions as to what was and was not safe.

Over a period of 2 years, the captain received several letters of appreciation from the SilkAir B737 Fleet Manager for being on standby. Such letters were standard for such events.

In addition, it is strongly suggested that the following events, which were presented in the HPG report (version 6.0) be added to Appendix I:

24 August: The captain and the first officer who had been involved in the go-around incident in March and the circuit breaker incident in June flew together as a result of a roster change that the captain had requested for personal reasons.

20 November: The captain was involved in an event that resulted in an overweight landing. There was an engine power problem noted during takeoff and climbout. After discussion with an engineer on board, the flight crew decided to return to Singapore instead of continuing to the destination airport. The subsequent overweight landing was not noted in the voyage report and technical log as was specifically required by company procedures. The crew also did not complete other paperwork associated with the flight including calculating the landing speeds, flight time, and fuel

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[12] Economy speed is a speed that is supposed to optimize the relationship between time enroute and fuel burn. It is a speed calculated to reduce the cost of operating the flight for the airline considering several economic factors and not a manufacturer-imposed operating limitation on the aircraft.

[13] A high approach means that during the descent from cruise, an airplane is at an altitude higher than the typical altitude for a given distance from an airport.

flight plan. The B737 Fleet Manager noted the discrepancies and sent both pilots letters the next day, instructing them to "please be more mindful."

10 December: The captain was flying with close friends, one was the first officer and the other was riding in the jump seat. During the flight, the captain complained about the B737 Fleet Manager and the letter he had received about the overweight landing incident on November 20. A variety of other topics were discussed (see recommended additions to section 1.18.3.4 Recent

11 December: The captain visited the Flight Operations Manager to discuss the letter about the overweight landing. The captain was concerned that he had been sent a negative letter about a minor issue and no mention had been made about the significant good work he had done to return the airplane to Singapore (according to the first officer on that flight, the captain effectively managed the increased workload that was associated with this air-turn back to Singapore including troubleshooting, making the necessary notifications to ensure that passengers'needs were met, and moving the airplane to the maintenance area). The Flight Operations Manager reported that he told the captain to send him a letter outlining his concerns and he would then consider whether to send him a "thank you" letter. The Flight Operations Manager did not receive a letter from the PIC outlining his concerns.

Finally, information in Appendix I regarding certain events in the captain's professional history that occurred before August 19, 1997, is noticeably condensed when compared to the discussion of the same events in the HPG report (version 6.0). Some of these events were addressed and acknowledged publicly by SilkAir following the AAIC interim report that was released in August 1999. Although this information may have been pared down for the sake of brevity, the NTSC should provide more information about the March 3, 1997, Manado event and the June 4, 1997, CVR circuit breaker event and the associated inquiries and appeals.

1.18.3.3 Financial Background Information

The financial background data of the PIC was gathered to determine whether financial factors could have affected the performance of the PIC.

PricewaterhouseCoopers was appointed by the NTSC to conduct an independent review of the preliminary findings of the NTSC's Human Factors Group concerning the financial background of the PIC. PricewaterhouseCoopers was not involved in the investigation itself. Based on the review, PricewaterhouseCoopers made certain recommendations to the NTSC in order for the NTSC to refine its findings.

At the time of the accident, the PIC operated a securities trading account in Singapore. This account was operated from June 1990 until the time of the accident. During 1990 – 1997 the PIC traded over 10 million shares, where the value and the volume of the trading increased significantly every year. The PIC's accumulated total losses from share trading increased between 1993 and 1997, with moderate gains during 1997. There was no period of the PIC negative net worth. The PIC's trading activities was stopped on two occasions due to the non-settlement of his debt, i.e. from 15 April to 15 August 1997 and again from 4 December 1997 until the time of the accident. On the morning of 19 December 1997, the PIC promised the remisier to make a payment when he returned from his flight.

The PIC had several loans and debts at the time of the accident. The PIC's (and immediate family's) monthly income was calculated to be less (about 6%) than their monthly expenditure at the time of the accident.

The probate document indicates that the PIC had a number of insurance policies which provided benefits on the event of his death. Most of these policies were taken out many years prior to the accident. In December 1997 he was required by the financial institution granting the property loan to take a mortgage insurance policy. The PIC underwent medical tests for the policy on 1 December 1997 and followed this with a formal application of 5 December 1997. The PIC did not specify the commencement date for the policy. On 12 December 1997 the insurance company informed the PIC that his application was accepted pending payment of the insurance premium. A cheque dated 16 December 1997 was sent to the insurance company by the PIC being payment for the premium. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997.

The HPG§ examination and evaluation of the captain§ and first officer§ overall financial status was understood to be sensitive and confidential for the purpose of publication, and the NTSC§ decision not to present the actual financial numbers in the report is respected. However, this section§ brevity is of concern

because it does not present the totality of information evaluated and analyzed by the HPG.

All of the participants in the HPG (representing Indonesia, Singapore, the United States and Australia) were involved with almost every aspect of the fact-gathering process regarding the captain's financial status, which spanned a period of more than 8 years before the accident. The HPG evaluated this aspect of the captain's life and in July 1999, determined through consensus of all members that at the time of the accident, the captain was experiencing significant financial difficulties (conclusion 14 in the HPG report version 6.0) The NTSC contracted Price-Waterhouse-Coopers (an auditing company) to conduct an audit of financial information that had been gathered during the investigation by the HPG and the NTSC in the latter stages of the investigation. Although the audit was completed, HPG members were not provided a copy for its review and evaluation. Given the significance of this information, the report and its content should be discussed in greater detail.

The review of section 1.18.3.3, revealed inaccuracies and exclusion of relevant information. The NTSC draft report briefly summarized the captain's stock trading over a period of 7 years. Although the actual number of stock shares that the captain traded is not relevant, the monetary value of the stocks traded, even approximated, is significant in that it demonstrates the financial burden that he was incurring in the later years. In addition, the NTSC draft report should contain specific information regarding the type of trading performed by the captain (that is, contra-trading versus buying normal shares) because it establishes that contra-trading, which the captain had been conducting for approximately 8 years, is a high-risk activity. Further, a complete discussion of the captain's trading activities would provide a basis for explaining his loss of trading privileges on two occasions because of nonpayment (the first time requiring a repayment plan that spanned months).

The NTSC draft Final Report misstates factual information developed by the AAIC HPG as of July 1999 concerning the mortgage insurance policy that became effective on the date of the accident. The NTSC draft Final Report states that mortgage insurance was "required" by the mortgage lender. However, the HPG found that mortgage insurance, which is purchased voluntarily, is generally recommended by the lender. Also, it should be noted that the loan secured for the purchase of this insurance had been established for at least 3 months before the policy was issued.

It is suggested that the following revisions be made to the draft Final Report to clarify existing information:

> The mortgage insurance application was submitted November 27, 1997. The insurance was recommended and not required as part of the loan taken by the captain in August 1997.

The captain had two training bonds that were in effect at the time of the accident, which required repayment had the captain voluntarily separated from SilkAir or was dismissed.

The statement that "The PIC's accumulated total losses from share trading increased between 1993 and 1997, with moderate gains during 1997," should be clarified to indicate that the captain had experienced net losses during this period.

In addition, the NTSC draft Final Report does not adequately present sufficient information regarding the captain's liquidity of assets at the time of the accident.

Finally, the statement, "The PIC had several loans and debts at the time of the accident" does not provide the specificity that is necessary to demonstrate the significant debt. Also, this statement does not address the significant amount of money that was due to be paid to the stock remiser at the time of the accident or the fact that there were no known liquid assets from which to pay this loan. Further, the draft Final Report does not address the credit cards debt that had been incurred by the captain at the time of the accident. A more thorough description of this information, even in general terms, is necessary to demonstrate that the captain's debts exceeded his assets. In addition, for clarity that maintains confidentiality of specific financial amounts, the report should be modified to characterize the magnitude of the captain's stock losses and debts about the time of the accident in terms of his average annual income.

1.18.3.4 Recent Behavior

The PIC's family reported that events and activities were normal in the days before the accident. The PIC was reported to have slept and eaten normally. There were no reported changes in his recent behavior. He was organizing his father's birthday party that was planned for 21 December 1997. No medical problems were reported or noted by airline's appointed medical clinics.

Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behavior.

The NTSC draft Final Report provides very brief information about the captain's activities in the days preceding the accident; however, excerpted information from the HPG report (final report and version 6.0) cites other pertinent information that documents the captain's behavior during the 45-day period prior to the accident. It is suggested that NTSC draft Final Report be revised to include the following

information:

> **The PIC's family reported that events and activities were normal in the days before the accident. The PIC was reported to have slept and eaten normally. No recent changes in his behavior were reported by his family. It was also reported that the PIC was assisting in preparations for his father's birthday party, which was to occur on December 21.**
>
> **Several work associates who observed the PIC on the day of the accident reported nothing odd or unusual in his behavior. One associate noted that the PIC was quite reserved in the briefing room but that he had behaved that way on some occasions.**
>
> **In the month prior to the accident, the PIC conducted flights on November 21, 22, 23, 28, 29 and 30, and December 10, 11, 12, 13 and 16. Some company personnel on these flights reported nothing unusual or noteworthy in the PIC's behavior. Some personnel reported that the PIC was quieter than normal, and other personnel reported that he complained about company management and its maintenance of aircraft. The following specific events were recounted:**
>
> **On December 10, the PIC was flying with close friends, one was the first officer and the other was riding in the jump seat. During the flight, the PIC complained about the B737 Fleet Manager and the letter he received about the overweight landing incident. A variety of other topics were also discussed. The PIC asked one of the other pilots about a crash involving a Malaysian Airlines B737 at Gelang Patah in 1984.[14] The PIC was also reported to have discussed the TWA800 B747 accident and mentioned the helplessness of a pilot in such an accident.**
>
> **The captain took leave from December 1 to 7, 1997. He applied for this leave on November 26, which coincided with school holidays.**

In addition, the NTSC draft Final Report does not include factual information related to the behavioral characteristics of both pilots that was developed by the HPG. The information is necessary for a complete understanding of the human factors aspects of the investigation and critical to a complete and proper analysis being accomplished.

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[14] The crash was determined to be the result of a hijacking. Information recorded on the CVR assisted authorities in making this determination. This information was told to the PIC during this flight.

Therefore, it is strongly recommended that the NTSC add a section that describes the behavioral characteristics of the captain and first officer. The new section for the captain should precede "Section 1.18.3.4 Recent Behaviour" in the draft Final Report (thereby making "Recent Behaviour" section 1.18.3.5) and be identified as "1.18.3.4 Behavioral Characteristics." This section should contain the following information:

The HPG found during its investigation regarding the captain that the RSAF did not require any psychological assessment during his career nor was such an assessment required or conducted for his employment with SilkAir.

HPG interviews with a variety of people who worked with the captain revealed that he was generally a quiet and reserved person. He would not initiate conversation with casual acquaintances but would talk if asked questions or shared a common interest with the other person. Some people described him as distant and difficult to get to know while other people described him as friendly and easy-going.

The captain's wife described him as a perfectionist and others who knew him in the RSAF described him as a typical fighter pilot. He was also described by people in the RSAF and SilkAir as a very assertive person; he would state his opinion if he disagreed with some professional issue, often in an undiplomatic manner. The interviews revealed that he was very confident and proud of his flying skills and was very proud of his RSAF experience. The captain was described as motivated to obtain the best for himself and it was reported that his career was important to him.

The HPG did find through interviews that there were no reports of the captain having any unusual or abnormal personal habits in the cockpit during flights and that it was routine for him to leave the cockpit to use the toilet, get a drink, or chat with the flight attendants.

The relationships between the captain and the three management pilots in SilkAir were reported to be quite cordial. It was reported that when he joined the company, management regarded him as a pilot who would have no trouble reaching a command position and who had the potential to become a management pilot. The managers were impressed with the captain's performance during his time as a first officer and as a captain. HPG interviews revealed that during this period, the captain often visited the Flight Operations Manager or the B737 Fleet Manager to offer suggestions to improve the company's operations. However, following the incidents and subsequent investigations in 1997, the captain's relationship with the B737 Fleet Manager became less amicable. Although there were no reported arguments, there was little interaction between them. The

captain continued to visit and communicate with the Flight Operations Manager but this relationship became somewhat strained after the captain lost his LIP status.

The captain was well respected by other Singaporean pilots in the company, was one of the first two Singaporeans to join SilkAir, and was one of the first two Singaporeans to be selected for command training. As such, he was regarded as a natural leader to the Singaporeans who subsequently joined the airline. The captain was one of several pilots who were involved in efforts to improve the employment conditions of Singaporean pilots. He was also known to defend other Singaporean pilots or encourage them to question any unfair treatment.

During the accident investigation, the HPG received reports that the captain did not have a good relationship with some of the expatriate pilots in the airline. Some of the pilots stated that the captain did not accept advice or criticism well from other captains. Further, some pilots also stated that that the captain had been promoted to LIP over more experienced captains who had airline instructional experience before coming to SilkAir. The Flight Operations Manager said that the captain was promoted because he had previous training experience in the RSAF, had a good record, and had all the markings of a good instructor. It was also stated that because he was Singaporean, he was preferred over expatriates.

The captain was generally popular among flight attendants and it was reported that he was typically easy-going and often joked with them. He never made any special demands, and he often completed sectors faster than other captains. Flight dispatchers also reported that the captain was easy-going and sociable. Line engineers reported that the captain was friendly, helped when there were engineering problems, and was quite reasonable about accepting any defects.

The HPG also received reports during its investigation that during the latter part of 1997, the captain criticized or complained about SilkAir management and the B737 Fleet Manager during flights. It was reported that he appeared to be upset about the inquiries that had taken place and his loss of LIP status and that he believed he had been unfairly treated. However, there were also reports that the captain had accepted his demotion.

It is also suggested that the appropriate section of NTSC draft Final Report be revised to include the information regarding the captain's use of medical leave to demonstrate a change in his behavior in the 3 months before the accident. For example, during his 6-year career at SilkAir, the captain visited the airline's preferred medical group on 31 occasions. No major, excessive, or extra-ordinary

> **medical problems were ever reported or noted. The PIC submitted six medical certificates, each requiring a day off flying duties during his SilkAir career. These occurred on August 1, 1995, July 23, 1996, August 10, 1997, October 1, 1997, and November 12 and 24, 1997. All certificates were associated with temporary conditions such as upper-respiratory tract infection, flu, or gastroenteritis.**

As previously stated, a section describing the first officer's behavioral characteristics should be added to the draft Final Report. This section should precede "Section 1.18.4.3 Recent Behaviour" in the draft Final Report (thereby making "Recent Behaviour" section 1.18.4.4) and be identified as "1.18.4.4 Behavioral Characteristics." The following information should be included:

> **During HPG interviews, the first officer was described as a quiet and reserved person. However, it was reported that if something needed to be said, he would say it. He was described as being mature for his age, confident, and likeable. The HPG received no reports of any interpersonal problems between the first officer and other pilots or other employees at SilkAir. There were no indications that he was experiencing any personal problems.**
>
> **While at Massey University, the first officer completed a California Personality Inventory. The results indicated that the he was well-adjusted, conservative, stable, and confident. There were no reports that the first officer had any unusual or abnormal habits in the cockpit during flights.**

The NTSC draft Final Report should also be revised to include information about the first officer's medical history while at SilkAir. Specifically, the first officer visited the airline's preferred medical group on three occasions, and no medical certificates were submitted requiring time off of work due to illness.

Additional Comments on NTSC Factual Section

Page 15, 1.12.3.2, Flight control surface diagrams should accompany the discussion of the spoiler actuators, leading edge flaps, etc., to facilitate the reader's understanding of these mechanisms.

Page 16, 1.12.3.3f, The statement, "As the actuator is of the piston type, the position may be indicative of the last position at impact," should be changed to read "As the actuator is of the piston type, the position may not be indicative of the last position at impact." This change would make the statement consistent with a similar statement made in section 1.12.3.3.a.

Pages 16 and 17, 1.12.3.3.g and 1.12.3.3.h, The heading for each paragraph should be changed to read "Aileron Power Control Units and Autopilot Servos" and "Elevator Power Control Units and Autopilot Servos" respectively.

Page 21, 1.16.4, Paragraph 3, The statement that the rudder balance weight separation did not occur "while the aircraft was cruising at FL350 but at a lower altitude" is correct. However, it should be emphasized that the balance weight separated after the airplane departed cruise flight. Thus, it is suggested that the sentence be revised to read "The rudder balance weight did not separate in while the aircraft was in cruise flight at FL350 but at a significantly lower altitude, after the airplane departed cruise flight."

Page 21, 1.16.4, This section only discusses the BASI trajectory study. The NTSB performed a "desktop" simulation that is referenced as Appendix G. The results of this simulation should be included in this section to provide a complete picture of the aircraft trajectory and break-up after departure from cruise flight.

Page 24, 1.18.2.3, There is no "Figure 15" as referenced in this paragraph.

Page 25, 1.18.3.2, Paragraph 4, It is suggested that instead of using the word "de-appointed" to describe the captain's loss of his LIP status, the words "demoted" or

2. ANALYSIS

2.1 Introduction

The following statement in section 2.1 should be clarified:

In accordance with Annex 13, a report was made to the relevant aviation security authorities in late 1999. While the technical investigation continued, aviation security authorities conducted a separate investigation, which is not covered in this report.

Currently there is no support text in the factual part of the NTSC draft Final Report that explains why the contents of the investigative report were made available to the relevant aviation security authorities. In accordance with ICAO Annex 13 requirements regarding suspicion or evidence that an accident was the result of a criminal act, paragraph 5.11 states "If, in the course of an investigation it becomes known, or it is suspected, that an act of unlawful interference was involved, the investigator-in-charge shall immediately initiate action to ensure that the aviation security authorities of the State(s) concerned are so informed." In the case of MI 185, this notification was necessary because the technical examination of the aircraft wreckage revealed there was no evidence of a mechanical malfunction of the aircraft structure, systems or powerplants that would have caused the aircraft to depart cruise flight. Further, the HPG developed sufficient personal background data pertaining to the captain to warrant the "relevant aviation security authorities" to conduct a further investigation of the captain.

2.3.3 Explanation to the Break Up of the Empennage

Close examination of the wreckage (Section 1.22) supports the results of the flutter analysis (Section 2.3.2) and the trajectory analysis (Section 2.3.1).

The above results suggest that the separation of the empennage parts could have had occurred at an altitude near or below 12,000 ft, due to an unstable flutter as the aircraft exceeded 1.2 Vd.

These two sentences may be misleading. To provide clarification, the NTSC draft Final Report should be revised to state that evidence indicates that the separation of the empennage components/parts was not the cause of the departure from cruise flight or the accident but was the result of an overspeed condition that occurred after the airplane departed cruise flight.

2.4 Power Control Units and Actuators

2.4.1 Main Rudder PCU

In the controlled laboratory test condition [Reference 16], it was found that problems due to thermal shock can arise. This can happen if the warm hydraulic fluid (at +77°C) rushes into a cold-soaked servo valve (at -40°C) causing the slides to expand against the valve housing. In such a temperature difference, a valve jamming could occur causing the rudder to move uncommanded or in a direction opposite to the rudder pedal command (rudder reversal). In real flight, the hydraulic temperature would not reach that high (+77°C) a level.

An introductory paragraph should be included in section 2.4.1 that explains why the rudder PCU was examined and described in greater detail than the other actuators/PCUs. This introduction would provide the reader with a brief background about the known rudder PCU anomalies identified in previous accidents and the reason for the additional examination.

Further, for clarification, the last two sentences in this section should be revised to read, In such a temperature difference, if the valve jams and the pilot commands additional rudder input, the result could be an unintended rudder movement in a direction opposite to commanded input (rudder reversal). However, the temperature of the hydraulic fluid rising to +77°C is not likely in normal in-flight operations.

Finally, this section should contain a conclusion statement that indicates that the investigation determined that the rudder PCU was not a cause or contributing factor in the accident.

2.4.5 Horizontal Stabilizer Jackscrew

A malfunction affecting both trim switches on a control wheel could also cause a run-away. It was not possible to ascertain if such an occurrence took place. However, had a run-away occurred due to a malfunction of the main electrical trim system, it would take about 10 seconds to change from 4.5 to 2.5 units (at a rate of trim change of 0.2 unit/sec at flaps retracted position). The trim wheel would turn continuously. The movement of the trim wheels and the sound produced would have been noticed by the pilots. Both pilots were trained to recognize such a condition and to take appropriate corrective actions.

This paragraph should be modified to include a conclusion that based on the evidence derived from the last recorded FDR position, the NTSB simulation and the physical evidence found during the wreckage examination, the stabilizer trim was

moved to the full nose-down limit through pilot input to the main electric trim system and not due to an 'uncommanded' or 'runaway' trim condition.

The effect of a system run-away of the horizontal stabilizer trim was simulated in the Garuda Indonesia Training Simulator as well as Boeing M-Cab Simulator, see Appendix G. A trim change from 4.5 to 2.5 units changed the aircraft attitude from a nose-up to a nose-down attitude. The simulator results showed that, with such a trim change, it took 1 minute and 23 seconds to descend from 35,000 feet to 19,500 feet. However, the last five ATC radar points showed a much faster descent of the accident aircraft, i.e. 32 seconds from 35,000 feet to 19,500 feet. Therefore, if the simulation was correct, the change of horizontal stabilizer trim position alone would not have resulted in the fast descent after leaving FL350.

The phrase in the preceding paragraph, 'If the simulation was correct' should be removed unless there are specific doubts regarding the accuracy of the simulation. If there is evidence to support the accuracy or inaccuracy of the simulation, this information should be discussed in detail in the factual and the analysis. Further, Boeing does not have any additional qualifiers about the simulation accuracy other than the verification by flight test to .89 Mach and extrapolation to .99 Mach.

2.4.6 Other Actuators

During the tear down examination, the following components were found to be in the stowed or retracted position:

- *Flight spoiler actuators*
- *Outboard ground spoiler actuators*
- *Inboard ground spoiler actuators*
- *Trailing edge flap ballscrews*
- *Leading edge flap actuators*
- *Leading edge slat actuators*
- *Mach trim actuator*
- *Thrust reverser actuators*

The fact that these actuators were found in the stowed or retracted position does not necessarily suggest that their respective systems were not activated during the descent. If the respective systems remained in the stowed or retracted positions, they would not have been factors contributing to the accident.

There was sufficient evidence to indicate that the actuators had performed as intended. Thus, this section should be modified to include a conclusion that there was no evidence of a mechanical malfunction or failure of any flight control PCU or actuator that either caused or contributed to MI 185's departure from cruise flight or the resulting accident.

2.6 Stoppage of the CVR and FDR

2.6.1 CVR Stoppage

The CVR recording ended while the aircraft was still cruising at an altitude of 35,000 feet, about seven minutes before the last radar return. Up to the CVR stoppage, the conversations in the cockpit was consistent with normal flight operation.

The CVR stoppage could have occurred due to a malfunction of the unit itself or a loss of power to the unit. The loss of power to the unit could be due to power interruption to the Electronics Bus 1 that supplies power to the CVR, short circuit or overload, CVR circuit breaker pulling or break in the wiring.

The entire two-hour recording was found normal. There were no observed anomalies when power was transferred on the ground in Jakarta. It appeared that the recorder's internal energy storage capacitor was operating normally by providing continuous recorder operation in spite of momentary aircraft electrical power interruptions, [Reference 4].

The examination of the CVR unit performed by the manufacturer (Appendix F) confirmed that the CVR was functioning properly. The recording had characteristics that would be expected of a normal electrical power shutdown of the CVR. Therefore, the stoppage of the CVR could be a result of the loss of power to the unit.

According to the aircraft wiring diagram 24-58-11 (Figure 16) the power to the CVR was from the Electronics Bus 1 (Elex Bus 1). The Elex Bus 1 also supplies power to other systems, such as the FDR, DME-1, TCAS, ATC-1 etc. Parameters of DME-1 and TCAS were recorded in the FDR. Analysis of the FDR recording showed that six minutes after the CVR stopped, the FDR was still recording TCAS and DME-1 parameters. This indicates that the CVR stoppage was not due to power loss at Elex Bus 1.

The CVR is equipped with an energy storage capacitor. The function of this capacitor is to provide power for 250 milliseconds after electrical power is removed from the unit such as when the aircraft power is switched from ground power to APU generators or the engine generators. Another function of this capacitor is to enable continued recording for another 250 milliseconds after power loss to the unit.

Had there been an overload or short circuit, the resultant popping of the CVR circuit breaker in the cockpit would have been recorded as a unique and identifiable sound signature by the CVR (see Section 1.11.1). Based on the examination of the results of the circuit breaker pull tests, there was no such sound signature in the MI 185 CVR recording found. This indicates that there were no short circuit or overload to cause the CVR circuit breaker to pop out.

The results of the CB pull tests showed that the sound signature associated with manual pulling of the circuit breaker is obscured by the cockpit ambient noise. Hence, no conclusion can be drawn whether the circuit breaker had been pulled manually.

A break in the wire supplying power to the CVR could also lead to CVR stoppage without any sound being recorded on the CVR. However, from the limited quantity of wiring recovered it could also not be determined if a break in the wiring had caused the CVR to stop.

Thus, the cause of the CVR stoppage could not be concluded.

The conclusions presented by the NTSC regarding the stoppage of the CVR are not in full agreement with the evidence. As previously stated in the comments to the factual portion of the draft Final Report, postaccident examination and testing proved that there were no mechanical malfunctions or failures of either the CVR or DFDR that would have caused the recorders to stop recording data.

Further, it is highly unlikely that the CVR lost power because of a broken wire, as the NTSC's analysis suggests, without a related "short circuit" or power loss to other systems in a related wiring bundle or electrical bus, which likely would have been reflected on the DFDR. If the short circuit had occurred, the circuit breaker would have popped, which would have been recorded on the CVR. NTSB tests established that if an "overloaded and a short circuit" condition had occurred, the sound of the circuit breaker popping is unique and loud enough to be identified on the CVR area microphone channel on the ground and in flight. No such sound was recorded on the CVR from MI 185.

Sufficient evidence has been documented, based on postaccident testing and examination, to conclude that the failure was not the result of a "fault" or the CVR "internal power supply and "hold up" capacitor, which appeared to be operating normally. Additionally, postaccident examination and testing revealed that the CVR recording exhibited characteristics that would be expected of a normal electrical power shutdown of the CVR.

2.6.2 FDR Stoppage

The FDR stopped recording at 09:11:33.7, or 6 minutes and 18.1 seconds after the CVR stoppage, and approximately 35.5 seconds before the aircraft started its descent, see Section 1.11.1 and Figure 2. Data recorded by the FDR indicates that the flight was normal until the FDR stoppage time. It was concluded that until the stoppage of the FDR, there were no indications of unusual disturbance (e.g. atmospheric turbulence, clear air turbulence, or jet stream upsets, etc.) or other events affecting the flight.

The FDR stoppage could have occurred due to a loss of power supply to the FDR, or the malfunction of the unit itself.

The recording of the ATC radar plots during the descent of the aircraft until 19,500 ft indicated that the aircraft ATC transponder continued operating after the FDR had stopped recording. SilkAir stated that generally flight crews use ATC-1 flying outbound from Singapore, and ATC-2 inbound. ATC-1 is on the same bus as the FDR, while ATC-2 is powered from Elex Bus 2, i.e. a different power source. No conclusion could be drawn as to the reasons for the CVR and FDR stoppage at different times.

The FDR was determined to be functioning normally until it stopped. The stoppage of the FDR could not be determined from the available data.

There were no evidence found that could explain the six-minute time difference between stoppage of the CVR and FDR.

The NTSC draft Final Report's discussion regarding the stoppage of the FDR needs to be revised to indicate that in addition to the possibilities mentioned, the DFDR's stoppage can also be explained by someone manually pulling the circuit breaker. This discussion should also be revised to reflect that the DFDR is powered through the same electrical bus (Electronics Bus 1) as ATC-1 (one of the airplane's two radar transponders) and the Mach trim actuator. The radar transponder (which was likely ATC-1 during the accident flight) continued to operate and return data for a short time after the DFDR stopped. In addition, the Mach trim actuator was found at its high speed (not cruise speed) setting, indicating that it was powered and operational during the airplane's high-speed dive. It can be concluded that the absence of a malfunction of the DFDR up to the point at which it stopped, combined with the fact that the transponder continued to transmit and the Mach trim actuator continued to operate after the DFDR had stopped, indicates that the stoppage was not due to a loss of power to Electronics Bus 1. However, the stoppage could be explained by someone manually pulling the circuit breaker.

The NTSC draft Final Report's discussion of the SilkAir practice of flight crews using ATC-1 when flying outbound from Singapore and ATC-2 when returning to Singapore is not documented in either the AAIC Operations or HPG reports. Further, this statement is contrary to information provided to the HPG group that the transponder in use during a flight typically corresponds to the pilot flying. Therefore, in the case of the accident flight, ATC-1 would have been selected. It is suggested that this statement be corrected.

Finally, the NTSC draft Final Report should include a discussion of human actions as a possible cause of the CVR and DFDR stoppage.

2.10 Simulated Descent Profile

The last five ATC radar points recorded represent the flight trajectory of the aircraft from the cruise altitude 35,000 feet to approximately 19,500 feet. Each point consisted of data relating to time, altitude and geographical coordinates.

Simulator tests and computer simulation fly-out studies were done to determine failures or combination of failures of the flight control and autopilot systems that could result in the extreme descent trajectory. Aircraft flight data were not available for the time period after the stoppage of the FDR. The initial condition for these tests and studies was cruise configuration at 35,000 feet based on the last known FDR data. The altitude range for the simulations was from 35,000 feet to approximately 19,500 feet.

The results of these simulation studies (Appendix G) are summarized as follows:

- *Any single failure of the primary flight controls such as hard-over or jamming of aileron, rudder or elevator did not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.*

- *Any single failure of the secondary flight controls such as hard over or jamming of yaw damper, or runaway of the stabilizer trim would not result in a descent time history similar to that of the last ATC radar points. In simulations of these flight control failure conditions the aircraft could be recovered to normal flight manually.*

- *Manipulation of the primary flight controls without horizontal stabilizer trim would result in a descent time history similar to that of the last ATC radar points. But this required large control column input forces and the aircraft was subjected to a loading exceeding 2 G. However, if the control column input forces were relaxed, in the simulations the aircraft would recover from the steep descent due to its inherent stability.*

- *Among other possibilities, a combination of changing the stabilizer trim from about 4.5 to 2.5 units and an aileron input could result in a descent time history similar to that of the last ATC radar points. This simulated descent trajectory would result in the aircraft entering an accelerating spiral and being subjected to a loading of less than 2 G. Furthermore, the aircraft would continue in the spiral even when the control forces were relaxed. This would result in a descent at a speed exceeding 1.2 Vd, in agreement with the analysis on the break up of the empennage as discussed in Section 2.3.*

Bullet 3 should be modified as follows for correctness and clarity:

Although manipulation of the primary flight controls without horizontal stabilizer trim would result in a descent time history similar to that of the last ATC radar points, this would require control column forces greater than 50 pounds and large control column inputs. However, the simulations indicated that if the control column input forces had been relaxed, the aircraft would have initiated a return to a nose-up attitude due to its inherent stability.

Bullet 4 should be modified as follows for correctness and clarity:

Among other possibilities, a combination of either control column inputs and/or changing the stabilizer trim from about 4.5 to 2.5 units, in combination with aileron inputs could result in a descent time history similar to that of the last ATC radar points. This simulated descent trajectory would result in the aircraft entering an accelerating spiral and being subjected to a loading of less than 2 G. Furthermore, the aircraft would continue in the spiral even when the control forces were relaxed. This would result in a descent at a speed exceeding 1.2 Vd, which is in agreement with the analysis of the breakup of the empennage as discussed in section 2.3.

Based on the data derived from the simulations, the following conclusion can be made regarding the maneuvers necessary for the airplane to fly a profile similar to that of MI 185:

No single mechanical failure of the airplane structure or flight control systems was found that would have resulted in movement of the airplane that matched the recorded radar data points. Further, there was no evidence of any combination of systems failures. Thus, no known or postulated mechanical failure was found that resulted in a flight profile that matched the radar data. However, changing the flight control input manually in multiple axes did provide a flight profile that matched the last recorded ATC radar data points. Therefore, it is probable that the airplane was likely responding to sustained flight control inputs from the cockpit.

2.11 High Speed Descent Issues

2.11.1 *Mach Trim System and its Function*

The aircraft was equipped with a Mach Trim system to provide stability at the higher operating speeds, i.e. higher Mach numbers. Mach trim is automatically accomplished above Mach 0.615. When the Mach Trim system is operative it will normally compensate for trim changes by adjusting the elevator with respect to the stabilizer, as the speed *increases. With the Mach Trim inoperative, the aircraft could exhibit a nose down tendency ("Mach Tuck") as speed increases. However, the expected control forces to overcome the "Mach Tuck" are light. Additionally when the speed exceeds the maximum limit, audible overspeed warnings are activated.*

Since the aircraft was cruising at subsonic speed (Mach 0.74) and trimmed for level flight, the aircraft will eventually return to the trimmed condition after a minor speed disturbance.

For the aircraft to dive, a significant disturbance resulting in an increasing speed must have taken place. Such a disturbance could be initiated by changing aircraft elevator or stabilizer trim. Should the airspeed increase to the point where it becomes transonic, and as the lift resultant moves aft and local supersonic flow develops, the nose-down pitching moment could be sufficiently large that the aircraft becomes speed unstable, i.e. continuing speed increase of the aircraft. Once the aircraft is in a transonic dive, recovery from the dive becomes more difficult because of an increase in control column forces due to the aircraft's increasing nose down pitching moment as well as a large reduction of elevator effectiveness due to the formation of shock induced air flow separation in front of the elevator.

It is possible to recover from a transonic dive by timely action of the pilot, by reducing thrust and deploying the speed brakes. Should the pilot not initiate a prompt recovery action, the recovery becomes more difficult.

During the tear down examination, the mach trim was found in the fully retracted position. The fact that this actuator was found in the retracted position may not necessarily indicate that the mach trim system is a factor contributing to the accident.

Because the Mach Trim system was not implicated as a cause or contributing factor in the accident, the discussion regarding this system is irrelevant. Therefore, it is strongly suggested that the discussion in this section be substantially reduced and that a definitive conclusion be included indicating that there was no evidence of a Mach Trim system failure that would have been causal or contributing to the accident.

2.11.2 Emergency Descent due to Fire, Smoke or Depressurization

An emergency descent is necessary when there is a rapid cabin depressurization or when a fire or smoke occurs in flight. The procedure is to simultaneously retard the thrust levers, deploy the speed brakes and bank the aircraft to initiate the descent. (Appendix K). Some forward stabilizer trim is applied to attain a dive which will accelerate the aircraft towards the maximum speed limit. Once the maximum speed is reached aircraft is re-trimmed to maintain the speed. This facilitates a limit on maximum rate of descent to the minimum safe altitude.

The last pilot radio transmission about two and a half minutes before the descent sounded normal and there was no mention of any in-flight fire or smoke. Furthermore, examination of the wreckage showed no evidence of in-flight fire or explosion.

Examination of the recovered oxygen generators showed that they were not activated. This indicated that there was no rapid depressurization at high altitude.

Based on the above findings, there was no indication of an emergency descent due to fire, smoke or rapid depressurization.

The first paragraph in this section is not a statement of analysis but of fact. The information presented refers to procedures (included in the NTSC draft Final Report as appendix K) to be employed by the flight crew in the event that an emergency descent is necessary. Moreover, the statement that the emergency descent procedures call for the pilot to "bank the aircraft to initiate the descent" is incorrect. The procedures do not specify banking the aircraft as the method to be used to initiate the descent. Because this information has no relationship to the accident and implies that a true emergency descent profile is similar to the derived profiles used in the simulator to match the accident descent profile, this statement should be removed. However, if it is to remain in the analysis, it must be corrected by removing the statement "banking the aircraft to initiate descent."

2.13 Human Factors Aspects of the CVR and ATC Recordings

2.13.1 CVR

(a) The conversations and sounds recorded by the CVR before it stopped were examined. The CVR transcript (Appendix A) showed that at 09:04:55 the PIC indicated his intention to go to the passenger cabin " .... go back for a while .... finish your plate.... ". At 09:05:00 the PIC offered water to the F/O, and at about the same time, several metallic snapping sounds were recorded. Thirteen seconds later, at 09:05:13.6 the CVR ceased recording. Analysis of the recording indicated that the metallic snapping sounds were made by a seatbelt buckle striking the floor. (See Section 1.16.2)

(b) During the period recorded by the CVR, all door openings or closings were related to pre-departure activities, in-flight meal service and normal pilot-cabin crew interaction. In the four minutes following the last meal service, there were no sounds associated with cockpit door opening or closing. After takeoff from Jakarta, conversations within the flight deck were between pilot-to-pilot, pilot-to-flight attendants, and normal pilot-to-ATC radio communications. During the flight, except for cabin attendants serving meals and drinks to the pilots, there were no indications of any other person(s) in the cockpit. It is concluded that after the last

meal service and until the stoppage of the CVR, the recording did not reveal any indications that person(s) other than the flight crew and cabin attendants attending to their duties were in the cockpit.

(c) Analysis of the CVR stoppage indicated that the failure of the CVR could not have been caused by a short circuit or overload. This is because either occurrence would have resulted in the CVR recording a "pop" sound which was heard on the test recording but not on the accident recording.

The CVR in-flight tests could not identify the sound of the CVR circuit breaker being manually pulled as the ambient noise obscured the sound made. The accident tape did not contain any identifiable sound attributable to manual pulling of the CVR circuit breaker. It was not possible to determine from the CVR tests if there was a pulling out of the CVR circuit breaker.

The information presented in paragraph (c) regarding the CVR is redundant. Because no conclusions are drawn, it is not necessary to discuss this information again.

In addition, as noted in the summary, this section should address the fact that the captain was in the process of leaving the cockpit at the time the CVR stopped recording. It should provide a description of the position of the CVR and DFDR circuit breakers in relation to the captain's seat, the door, etc. Finally, the information about the captain's previous CVR event (in June 1997) should be emphasized.

2.13.2 ATC Recordings

The data transcribed from the ATC communications recording of the air-to-ground conversation indicates that at 09:10:26, or 5 minutes and 10.4 seconds after the CVR stoppage, the F/O acknowledged the "abeam Palembang" call from the ATC. The F/O was positively identified by voice analysis examination. This confirms that the F/O was in the cockpit when the aircraft was abeam Palembang. However, it is not possible to conclude whether the PIC was in the cockpit at the time. It was also not possible to determine events or persons present in the cockpit from the time of the last transmission to ATC.

The absence of a distress call could suggest that the pilots were preoccupied with the handling of an urgent situation. However, it is not possible to conclude on the reason for the absence of a distress call.

The NTSC's conclusion that the absence of a distress call likely indicates that the pilots were attempting to "handle an urgent situation" is misleading because it

implies that the pilot(s) perceived the situation as an emergency. The discussion in this section should be modified to make clear the possibility that the absence of a distress call could suggest that the pilot(s) did not consider the situation a condition of distress, that is, the airplane was doing what a pilot commanded it to do.

2.14 Specific Human Factors Issues

In this section, the specific, personal, financial backgrounds and recent behavior of the PIC and the F/O are examined.

2.14.1 Personal Relationships

Evidence obtained from family and friends of both the PIC and F/O reported no recent changes or difficulties in personal relationships.

It was concluded there was no evidence that either pilot was experiencing difficulties in any personal relationships.

2.14.2 First Officer (F/O)

The investigation into the F/O's personal and professional history revealed no unusual issues. No records of incidents or unusual events were found, and no career setbacks or difficulties were experienced. Financial records showed no evidence of financial problems. Interviews with family, close friends and relations seem to indicate that the F/O was a well-balanced and well-adjusted person, and keen on his job, and planning to advance his a flying career. There were no reports on recent changes in his behavior.

2.14.3 Pilot-in-Command (PIC)

The investigation into the personal and professional career revealed that the PIC was considered to have been a good pilot, making his transition from a military pilot to commercial pilot smoothly. His career at SilkAir showed that he was well accepted and given higher responsibilities. He was considered to be a leader among the Singaporean pilot community in SilkAir.

During his professional career at SilkAir, he was involved in a few work-related events, which were in general considered minor operational incidents by the management. However in one particular event, for non-technical reasons the PIC infringed a standard operating procedure, i.e. with the intention to preserve a conversation between the PIC and his copilot, the PIC pulled out the CVR circuit breaker, but the PIC reset the circuit breaker in its original position before the flight. This was considered a serious incident by the management, and the PIC was relieved of his LIP appointment. The PIC was known to have tried through existing company procedures to reverse the management decision. Although there were some indications of the PIC being upset by the outcome of *the events, the magnitude of the psychological impact on the PIC could not be determined.*

The PIC's financial history was investigated for the period from 1990-1997. Based on the data available to the NTSC it was noted that the PIC's accumulated losses in share trading increased between 1993 and 1997 and his trading activity was stopped on two occasions due to non-settlement of his share trading debt. The data available also showed that his loans and debts were greater than his realizable assets and his monthly income (including his immediate family's income) was less (about 6%) than his estimated monthly expenses at the time of the accident.

2.14.4 Recent Behaviour

The PIC's recent behaviour was analysed from statements made by family members, friends and peers during interviews. The PIC's family reported no recent changes in his behaviour. Work associates who observed the PIC on the day of the accident and on his most recent flights, reported nothing odd or unusual in his behaviour.

2.14.5 Insurance

Based on the data available, it was found that at the time of the accident, the PIC had a number of life insurance policies. The majority of these were taken up earlier in his life. The most recent policy was a mortgage policy which was required by the financial institution from which he took the loan for his house in line with normal practice for property purchases in Singapore. The PIC applied for the mortgage policy on 27 November 1997. The insurance company approved the policy on 12 December 1997 pending payment of the first premium. The PIC submitted a cheque dated 16 December 1997 for the first premium payment. The commencement or the inception date of the policy was set by the insurance company to be 19 December 1997. This information was not conveyed to the PIC. The cheque was cleared on 22 December 1997. From the data available to the NTSC there was no evidence to indicate if this mortgage policy has any relevance to the accident.

NTSC concluded that the combination of financial situation and his work related events could be stressors on the PIC. However, NTSC could not determine the magnitude of these stressors and its impact on the PIC's behavior.

The deficiencies, inaccuracies, and omissions of relevant information pertaining to the captain's and first officer's personal, career, and financial backgrounds have been previously discussed. It is imperative that complete and accurate factual information be presented for analysis so that a proper and thorough analysis can be accomplished. The factual information suggested for inclusion will serve as the basis for revising the analytical discussion and conclusions of the human factors issues in this section.

Finally, it should be noted in this section that the captain had been told that the insurance policy would go into effect upon receipt of the first premium payment.

3. CONCLUSIONS

3.1 Findings

Engineering and Systems

- *There was no evidence found of in-flight fire or explosion.*
- *From flutter analysis and wreckage distribution study, the empennage break-up could have occurred in the range between 5,000 and 12,000 feet altitude.*
- *Examination of engine wreckage indicated that the conditions of the engines at impact were not inconsistent with high engine rotation speed. No indications were found of in-flight high energy uncontained engine failures. Therefore, the engines were considered to be not a factor contributing to the accident.*
- *Examination of the actuators of flight and ground spoilers, trailing and leading edge flaps, as well as engine thrust reversers indicate retracted or stowed positions of the respective systems.*
- *Examination of the main rudder power control unit (including the servo-valve), the yaw damper modulating piston, the rudder trim actuator, the rudder trim and feel centering unit, the standby rudder PCU, the aileron PCUs, the elevator PCUs, and the horizontal stabilizer jack-screw components, revealed no indications or evidence of pre-impact malfunctions.*

Based on the evidence and postaccident testing, a definitive conclusion can be made regarding the flight control systems. Therefore, it is suggested that the NTSC§ draft Final Report be modified to include the following:

> **There was no evidence of a mechanical failure of any of the flight control systems or related components that would have been causal or contributing to the accident.**

Also, it is suggested that the following conclusion be added for completeness:

> **Separation of the empennage components/parts were not the cause of the departure from cruise flight or the resulting impact with terrain but, rather, were the result of an overspeed condition that occurred after the airplane departed cruise flight.**

- *Examination of the 370 kg of recovered electrical wires, connectors and circuit boards showed no indication or evidence of corrosion, shorting, burning or arcing in these wires or parts.*
- *The CVR stopped recording at 09:05:15.6 and the FDR stopped recording at 09:11:33.7. The examination of the CVR and FDR showed no malfunction of the units. The stoppages could be attributed to a loss of power supply to the units. However, there were no indications or evidence found to conclude on the reason for the stoppages due to the loss of power. The cause of the CVR and FDR stoppages and the reason for the time difference between the stoppages could not be concluded.*

The NTSC draft Final Report suggests that the cessation of the CVR and DFDR could in each case be explained by a broken wire. Although this is technically correct, the probability of two such unrelated wire breaks occurring several minutes apart and affecting only the CVR and DFDR is so highly improbable that it cannot be considered a realistic possibility.

- *The inspection of the aircraft maintenance records did not reveal any defects or anomalies that could have affected the airworthiness of the aircraft or that may have been a factor contributing to the accident.*
- *The horizontal stabilizer trim was found to be in the 2.5 units position which matched the forward nose-down limit of the manual electrical trim.*

This conclusion should be expanded to include a definitive statement that the 2.5 units of nose-down trim was the result of a sustained manual input and not attributed to a malfunctioning system resulting in a "runaway."

Flight Operations

- *Weather and Air Traffic Control were not factors contributing to the accident.*
- *Audio spectral analyses on Air Traffic Control communications and the accident CVR indicate that the last communication from the MI 185 at 09:10:26, occurring at a position approximately abeam Palembang was performed by the F/O.*
- *The examination of the flight deck noise and sounds concludes that the metallic snap recorded on the CVR was made by a seatbelt buckle hitting against a metal surface.*
- *Based on flight simulations, it was observed that the simulated descent trajectory resulting from any single failure of flight control or autopilot system would not match the radar data.*
- *Based on the same flight simulations, it was also observed that the trajectory shown by the radar data could have been, among other possibilities, the result of the*

combination of lateral and longitudinal inputs together with the horizontal stabilizer trim input to its forward manual electrical trim limit of 2.5 units.

To clarify the conclusion at bullet 5, it is suggested that the following sentence be added to the end:

Despite the stabilizer trim being at the 2.5 unit nose-down setting (its forward limit), the aircraft would have remained controllable and appropriate flight control input would return the airplane a normal flight attitude.

Additionally, the following should be added to the draft Final Report:

No single mechanical failure of the airplane structure or flight control systems was found that would have resulted in movement of the airplane that matched the recorded radar data points. Further, there was no evidence of any combination of systems failures. Thus, no known or postulated mechanical failure was found that resulted in a flight profile that matched the accident radar data. However, changing the flight control input manually in multiple axes did provide a flight profile that matched the last recorded ATC radar data points. Therefore, it is probable that the airplane was likely responding to flight control inputs from the cockpit."

Human Factors

- *Both pilots were properly trained, licensed, and qualified to conduct the flight.*
- *There was no evidence found to indicate that the performance of either pilot was adversely affected by any medical or physiological condition.*
- *Interviews with respective superiors, colleagues, friends and family revealed no evidence that both the flight crew members had changed their normal behaviour prior to the accident.*

This conclusion is not representative of the findings of the HPG investigation. Although consistent with the HPG's conclusion (in HPG report Version 6.0, July 30, 1999) regarding the first officer, the conclusion in the draft report is inconsistent with the HPG's conclusion regarding the captain. The HPG report states, "There were some indications that the captain's behavior or lifestyle changed prior to the

accident." It is suggested that this conclusion be separated to accurately describe the captain's and first officer's behavior.

- *There was no evidence found to indicate that there were any difficulties in the relationship between the two pilots either during or before the accident flight; or had been experiencing noteworthy difficulties in any personal relationships (family and friends).*
- *Until the stoppage of the CVR, the pilots conducted the flight in a normal manner and conformed to all requirements and standard operating procedures.*
- *Although a flight attendant had been in the cockpit previously, after the last meal service and until the stoppage of the CVR there was no indication that anyone else was in the cockpit other than the two pilots.*
- *In the final seconds of the CVR recording the PIC voiced his intention to leave the flight deck, however there were no indications or evidence that he had left.*
- *Interviews and records showed that in 1997 the PIC had experienced a number of flight operations related events, one of which resulted in his being relieved of his LIP position.*

In its evaluation of the data collected, the HPG made a more definitive conclusion regarding the captain's career in the 6 months prior to the accident. The HPG conclusion, "During 1997 the PIC experienced multiple work-related difficulties, particularly during the last 6 months" should be used to modify the existing conclusion.

- *The PIC was involved in stock-trading activities, but no conclusions could be made indicating that these activities had influenced his personal behavior.*

The first part of this conclusion, "The PIC was involved in stock-trading activities" is a statement of fact and does not provide the basis for a conclusion. Further, the factual report substantiates that at the time of the accident, the PIC had been requested to pay a significant amount of money for outstanding debts and did not have liquid assets from which to pay these debts. This latter information forms the basis for a conclusion regarding the captain's financial stressors. In the HPG report, the conclusion was made that "At the time of the accident the PIC was experiencing significant financial difficulties." Also, this information was presented in the NTSC's interim report issued August 1999. Therefore, it is suggested that the NTSC revise this conclusion to be consistent with information cited in the AAIC HPG report and that was disseminated to the public in 1999.

- *From the data available to the NTSC there was no evidence found to indicate if the mortgage policy taken out by the PIC in connection with his housing loan has any relevance to the accident.*

Finally, the NTSC's conclusions do not address the crash of the three training aircraft from the captain's squadron while he was serving in the military. As discussed in the comments to section 1.18.3.1, the HPG examined the effect this event may have had on the captain but could not determine the extent to which he may have been affected. It is strongly suggested that the NTSC's draft Final Report include the conclusion from the AAIC HPG report that states, "The accident [in Palembang] occurred on the same date as the 1979 RSAF crash in the Philippines; the extent to which the PIC was affected by this event could not be determined."

3.2 Final Remarks

- *The NTSC investigation into the MI 185 accident was a very extensive, exhaustive and complex investigation to find out what happened, how it happened, and why it happened. It was an extremely difficult investigation due to the degree of destruction of the aircraft resulting in highly fragmented wreckage, the difficulties presented by the accident site and the lack of information from the flight recorders during the final moments of the accident sequence.*
- *The NTSC accident investigation team members and participating organizations have done the investigation in a thorough manner and to the best of their conscience, knowledge and professional expertise, taking into consideration all available data and information recovered and gathered during the investigation.*
- *Given the limited data and information from the wreckage and flight recorders, the NTSC is unable to find the reasons for the departure of the aircraft from its cruising level of FL350 and the reasons for the stoppage of the flight recorders.*
- *The NTSC has to conclude that the technical investigation has yielded no evidence to explain the cause of the accident.*

The technical investigation has, in fact, yielded sufficient information, which was derived through the on-scene and postaccident investigation activities, to definitively conclude that there were no mechanical anomalies with the aircraft, there were no environmental anomalies, nor were there any other significant technical factors that would have caused or contributed to the accident.

Additionally, the statement regarding the participating organizations in bullet 2 is made with a level of certainty that may not truly reflect the opinions of the "participating" organizations. Further, the remaining concluding statements do not necessarily reflect an analysis of all of the facts, conditions, and circumstances revealed during the course of this accident investigation.

3 RECOMMENDATIONS TO MANUFACTURERS

1. *It is recommended that a comprehensive review and analysis of flight data recorders and cockpit voice recorders systems design philosophy be undertaken by aircraft and equipment manufacturers. The purpose of the review and analysis would be to identify and rectify latent factors associated with stoppage of the recorders in flight, and if needed, to propose improvements to ensure recording until time of occurrence.*

2. *It is recommended that a review of the flight recorders design philosophy be undertaken by aircraft and equipment manufacturers to include recording of actual displays as observed by pilots in particular for CRT type of display panels.*

3. *It is recommended that a review of the flight crew training syllabi be undertaken by aircraft manufacturers to include recovery from high speed flight upsets beyond the normal flight envelope. The purpose of developing the additional training is to enhance pilot awareness on the possibility of unexpected hazardous flight situations.*

4 GENERAL RECOMMENDATION

4. *It is recommended that regional investigation framework for co-operation in aircraft accident investigations be established to enable fast mobilization of resources and coordination of activities to support those states that do not have the resources and facilities to do investigations on their own.*

The factual evidence does not support recommendations 1 and 3 because the postaccident tests and examination suggest that the CVR stopped recording as a result of the unit§ circuit breaker being pulled. This scenario also likely explains why the DFDR stopped recording.

The investigation did not reveal any evidence to suggest that a mechanical malfunction or failure of a particular system caused an unexpected upset. If such a scenario had occurred, the flight crew should have been able to take immediate corrective action because they had received training at SilkAir in the recovery from unusual attitudes. Based on the evidence, the departure from cruise flight was likely an intentional maneuver; therefore, recommendation 3 is without merit.